STAT

CHANGES IN VARIOUS PHYSIOLOGICAL AND BIOCHEMICAL PROCESSES UNDER THE INFLUENCE OF HEAVY MUSCULAR STRESS

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The present communication sets forth the results of one stage of work in studying the effect of heavy muscular stress on animal organisms. Having conducted our research within the framework of G. V. Fol'bort's plan of activity, we have taken into account all the major propositions he formulated on the connection between the processes of exhaustion and recovery.

Our study was devoted to changes in the electrocardiogram and in protein metabolism when dogs were subjected to heavy muscular stress. The 2 types of observation were conducted simultaneously with the same dogs, as it seemed appropriate to us to compare changes in physiological and biochemical processes occurring during a single experiment. I. P. Pavlov pointed to the necessity for this type of experiment in his work on the processes of exhaustion and recovery of the salivary gland.

The literature contains references to studies of the relationship between muscular activity and nitrogen metabolism. The data thus obtained testify directly and indirectly to changes in nitrogen metabolism in muscular activity. In studies during recent years (Savron', Kunchuliya) on animals and rabbits, the authors demonstrated that muscular activity is accompanied by

elevated excretion of products of protein decomposition.

The object of our study was to investigate changes in protein metabolism under the influence of severe muscular strain in dogs. The change in protein metabolism was studied under dynamic conditions: prior to and after application of muscular load, during the period of recovery.

We chose the electrocardiogram as the means of characterizing canine cardiac activity, because it offers a better means than any other of determining, albeit indirectly, the metabolic processes in cardiac muscle. Of primary interest to us was a clarification of the changes specifically in the metabolism of cardiac muscle during heavy muscular work by the animal, and in rest thereafter.

Many physiologists and clinicians (Smirnov, Letunov, Borisova and Rusinov, Kiselev and Rakhlin, Lang, etc) associate the tail of the electrocardiogram and, primarily, the T wave, with metabolic (in Smirnov's opinion, restorative) processes in cardiac muscle.

The results of a series of studies in which the subjects were usually athletes indicate that intensive physical stress does produce the greatest change specifically in the terminal components of the electrocardiogram. Our prior research (A. G. Filippova, "Changes in the Electrocardiogram under Physical Stress," communications I, II, Voprosy fiziologii [Problems of Physiology], Nos 9, 10) with dogs has shown that severe muscular stress results in change in all the components of the electrocardiogram (waves and intervals), but that the greatest changes occur toward the end, in the S-T segment and the T wave. In most experiments these changes move in a single direction, but they differ in degree, and do not always

reveal dependence upon the degree of load. In some animals even exceptionally heavy stresses did not produce marked changes in the electrocardiogram. As a result, we are in complete agreement with the conclusion of S. P. Botkin to the effect that heavy physical labor is only one of the factors involved in the tiring of the heart.

Method

The experiments were run on 3 dogs in metabolism cages and kept on a constant ration.

All the dogs were of the same age and sex and had grown up under identical conditions. The muscular stress consisted of causing them to run in a treadmill with a load on their backs, usually constituting 63 to 70% of bodyweight. The rate at which they ran was 5.5 km/hr. The dogs ran until they could run no longer, 2 of them keeping it up for 120 to 180 minutes, while the other quit after 50 to 60 minutes.

Study of protein metabolism was by comparative analysis of daily urine for 4 to 5 days before the experiment, during the day of experiment, and for 5 to 7 days during the period of recovery. Total urine nitrogen was determined by the Kjeldahl method, and total urea by the urease method. It was impossible for the feeding regimen to affect excretion of nitrogen with the urine. The experiment with muscular load was set up after the daily urine nitrogen had reached a given level. During the research the dogs showed a positive nitrogen balance or a state of nitrogen equilibrium.

The electrocardiograms were taken in the 3 standard leads and in the usual manner, with an EKP-4, before the load-carrying dogs began to run, at various times while they were running, and during 60 to 80 minutes after they stopped.

The dogs were weighed and rectal temperature taken before and after the experiments.

Results

Under heavy muscular stress most of the dogs showed specific changes in electrocardiogram, pulse, rectal temperature, weight, and protein metabolism.

The changes in pulse and electrocardiogram were of the same nature as in the experiments previously described. Toward the end of the run, the dog's pulse increased 35 to 100 beats per minute. In the subsequent 60 minutes of rest the pulse of some of the animals dropped to the initial level, or even below. In most of the dogs it remained at a rate of 15 to 20 beats per minute.

The electrocardiogram taken immediately after running showed the P-Q to be shortened by 0.01 to 0.03 second, and the QRST by 0.03 to 0.08; while the second and third leads showed an increase in the P and T waves. The T wave, diphasic or negative before the run, became positive at the beginning of the run. At the end of the run with load, the positivity of the T-wave declined in a number of experiments, and sometimes became negative. The stress caused a decline in all the waves in the first lead, and the Q of the second and third. During the rest period there was an increase in the waves of the first lead, and the Q of the

second and third. The P and T remained elevated for a period, and in some instances continued to rise. At the end of the rest period the T wave usually declined, often becoming diphasic or negative. During the rest period the QRST segment usually increased by 0.02 to 0.05 second. As in our former experiments, removal of the load instantly produced marked changes in the ECG.

The nature of the changes was identical in all experiments, but their profundity differed somewhat, particularly in different animals. In certain animals the changes were sustained for a period of several days.

At the end of the run the rectal temperature proved to be elevated by 1.4 to 2.8°C. During the rest period the temperature dropped sharply, falling by 0.4 to 1°C, relative to the initial temperature, during the first 20 to 30 minutes after running, and by 2.3 to 3° relative to that measured immediately after running (see Table).

After running with the load, a decline in the animal's weight by 1.7 to 5.3% was noted. In most cases weight returned to normal within 1 or 2 days.

In virtually all the experiments the excretion of total nitrogen and of urea nitrogen increased after physical stress. This increase varied from day to day in individual animals. Thus, in certain experiments, the total nitrogen and urea nitrogen during the day of experiment increased by 13 to 24%, returning the next day to the initial level. In other experiments the quantity rose by 100 to 130% and remained elevated for 2 to 5 days after the experiment with physical load. During this first stage of

the work we were unable to discover the reasons for these fluctuations.

CHANGES IN PHYSIOLOGICAL AND BIOCHEMICAL INDICES UNDER SEVERE STRESS (DOGS BOY AND TARZAN)

Dog and Expt No	Load, % of body weight	Time of run, minutes	Rise in temperature, °C	Weight loss, %	% rise in nitrogen excretion	Rise in pulse/min	
						before stress	after stress
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Boy							
1	64.2	180	1.7	5.3	16	81	170
2	64.7	180	1.7	3.6	13	85	170
3	65	180	2	3.5	-	82	180
4	65.3	130	2	3.5	134	72	180
5	67.7	70	2	2.96	13	100	170
6	68.7	120	1.8	3.5	6.4	106	170
7	70.6	90	2.8	3.5	0	97	195
8	49.5	180	1.4	1.7	24	115	133
Tarzan							
1	63.4	175	2.4	8.6	53	80	150
2	66.7	90	2.2	3.9	100	80	165

In most experiments we observed correspondence between the biochemical and physiological changes on severe muscular stress. In experiments in which changes in electrocardiogram, pulse, and temperature were marked, there was an even greater rise in urine nitrogen. As an example, we cite the findings with Tarzan. After a relatively brief run (90 minutes) he showed a considerable increase in pulse rate, elevation of temperature, and a marked change

in electrocardiogram. A considerable increase in nitrogen was observed in the daily urine after the experiment (Figures 1a and 1b). However, this parallelism was lacking in a number of experiments. In one experiment the dog Boy showed an extraordinary rise in excretion of total and urea nitrogen (by 134%), while the changes in the electrocardiogram were also considerable but less marked than in other experiments in which changes in urine nitrogen were distinctly lower and, in addition, appeared only toward the end of the rest period (Figures 2a and 2b).

In another experiment exceedingly sharp changes in electrocardiogram, but relatively minor changes in total and urea nitrogen (13%), were observed. The duration of the dog's run in this experiment was only about half as long as in the prior case (Figures 3a and 3b). In the preceding experiment the dog had run rather well for 120 minutes, only then beginning to show signs of excitation and refusing to run, quitting after 130 minutes. In the second experiment the dog showed marked excitation shortly after starting to run. After 70 minutes the experiment was stopped, due to marked resistance to running. The considerable changes in electrocardiogram in this instance were apparently explained by the state of excitation which the dog had entered, and the insignificant change in protein metabolism was the consequence of the brief duration of the work. On the other hand the longer period of work in the first experiment, performed by the animal for a considerable period with no signs of excitation, produced shifts in protein metabolism but did not lead to sharp changes in electrocardiogram, due to the high adaptability of the cardiac muscle to the load.

As previously noted, restoration of nitrogen to the initial level was different in the different animals. In virtually every case, subsequent to physical stress, the urine nitrogen either returned to normal on the very next day or remained somewhat elevated for a number of days. However, with Tarzan in one of these experiments, the change in urine nitrogen, quite marked during the day of the experiment, increased still further the next day (Figure 4).

Thus, severe physical stress caused changes in protein metabolism and cardiac activity in dogs, the changes often being parallel.

Summary

1. Heavy physical stress (running dogs carrying weights on their backs), accompanied by changes in electrocardiogram, temperature, and weight, resulted in an increased excretion of protein decomposition products (total and urea nitrogen) in the urine.

2. Changes in the electrocardiogram and in protein metabolism was of varying intensity in different experiments.

3. In a number of experiments we observed a correspondence between the intensity of the changes in electrocardiogram and in protein metabolism, while other experiments failed to produce this. The marked changes in electrocardiogram occurring in certain animals against a background of little change in protein metabolism can probably be explained by the high state of excitation of the animal during the experiment.

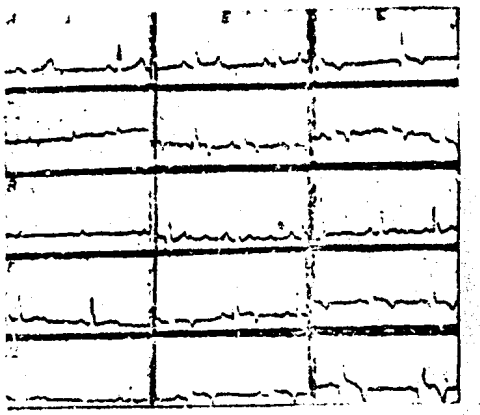

Figure 1a. Tarzan. Experiment 2. 90-minute run carrying load equal to 66.7% of body weight at 5.5 km/hr. Electrocardiogram taken in 3 leads. A, before run; B, 90 minutes after run had started; C, 10 minutes after dog stopped running; D, 30 minutes after dog stopped running; E, 60 minutes after dog stopped running.

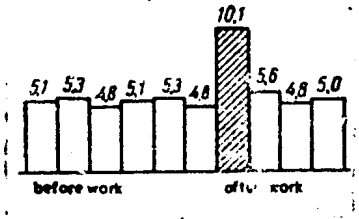

Figure 1b. Tarzan. Experiment 2. Dynamics of excretion of total nitrogen (in g). Cross-hatched column represents day of experiment.

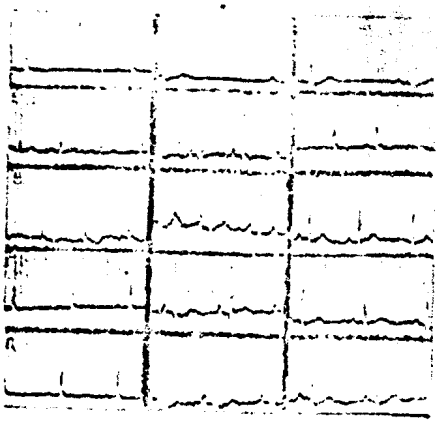

Figure 2a. Boy. Experiment 4. 130-minute run carrying load equal to 65% of body weight at 5.5 km/hr. Electrocardiogram in 3 leads. A, before run; B, 130 minutes after start of run; C, 10 minutes after end of run; D, 3 minutes after removal of weight; E, 30 minutes after end of run.

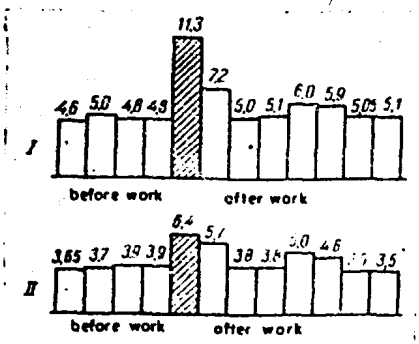

Figure 2b. Boy. Experiment 4. Dynamics of excretion, total nitrogen (I) and urea nitrogen (II) (in g). Cross-hatched column represents day of experiment.

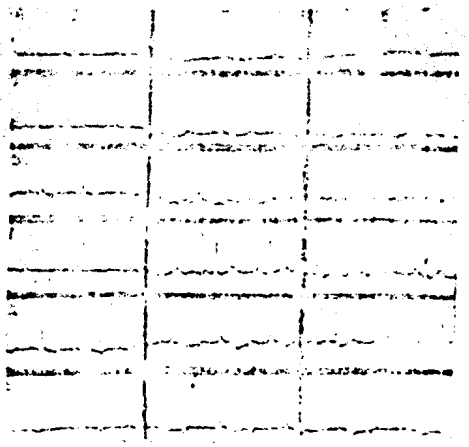

Figure 3a. Boy. Experiment 5. 70-minute run at 5.5 km/hr with load equal to 67.5% of body weight. Electrocardiogram in 3 leads. A, before run; B, after attachment of load; C, 70 minutes after start of run; D, 15 minutes after end of run (dog standing still with load); E, 10 or 15 seconds after removal of load; F, 60 minutes after end of run.

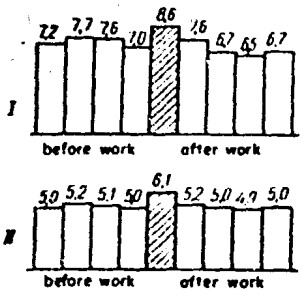

Figure 3b. Boy. Experiment 5. Dynamics of excretion of total nitrogen (I) and urea nitrogen (II), g. Cross-hatched column shows day of experiment.

Figure 4. Tarzan. Experiment 1. 170-minute run at 5.5 km/hr with load equal to 63% of body weight. Grams total nitrogen (I) and urea nitrogen (II) excreted. Cross-hatched column corresponds to day of experiment.